Secondary Task and Situation Awareness, a Mobile Application for Conditionally Automated Vehicles

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Abstract
Autonomous vehicles are developing rapidly and will lead to a significant change in the driver's role: s/he will have to move from the role of actor to the role of supervisor. Indeed, s/he will soon be able to perform a secondary task but s/he must be able to take over control when a critical situation is not managed by the driving system. The role of new interfaces and interactions within the vehicle is important to take into account. This article describes the design of an application that provides the driver with information about the environment perceived by the vehicle. This application is displayed as split screen on a tablet by which a secondary task can be performed. The results of initial experiment showed that the participants correctly identified all the factors limiting the proper functioning of the driving system while performing a secondary task on the tablet.

Author Keywords
Conditionally automated driving; human-vehicle interaction (HVI); mobile application; secondary task; situation awareness; user test

CCS Concepts
•Human-centered computing → Graphical user interfaces;

Introduction

The automotive industry is undergoing a deep change process today as a result of the implementation of increasingly automated systems, tending towards complete autonomous driving. For now, the driver still has to fully monitor his environment and cannot perform a non-driving related task. According to the classification proposed by SAE [16], Level 3 vehicles allow the driver to perform a secondary task without needing to constantly monitor the environment. If the driver engages in another task, the latter will find itself outside the control loop and handover will appear more difficult by demanding a higher cognitive load [10]. However, the driver must still be able to regain control of the vehicle when requested by the vehicle. For these reasons, it is important to develop Human-Vehicle Interactions (HVI) that allow the driver to maintain awareness of his/her environment while engaging in a secondary task, in particular, avoiding cognitive overload or underload.

In this article, we propose to transmit different information related to the vehicle environment on a tablet via an Android application. The purpose is to allow the driver to perform a secondary task while maintaining his/her awareness of the environment of the car in order to be able to perform efficient takeovers if necessary. In addition, the use of a tablet or smartphone does not require any additional interfaces on the car or user (ambient display, headphones...) and they could be easily integrated into a level 3 vehicle with the sole condition of being able to retrieve the information collected by the vehicle. The application is also in charge of forwarding the request for a takeover in case of a critical situation.

State of the art

Analysis of SA and TOR interfaces

As a first step, we analyzed interfaces for increasing the driver's Situation Awareness (SA) in the context of conditionally automated driving. The study lead by Miller et al. [21] proposes to use a tablet to display Take Over Requests (TOR) but it did not provide any information about the vehicle's environment. So far, the proposed interactions are mainly visual (ambient lights on the central console and both side pillars [20], augmented reality on the windshield [23]), sound (alarms in critical situations [24], even spatialized alarms [4]) and haptic (vibrations in back seat [14], steering wheel shape change [22]). Literature of TOR demonstrated their use as a main research topic in the context of HCI [5], [13], [19], but also as an evaluator of SA [17]. The acceptance of TOR by users was also studied [3], with several conclusions to be considered, such as the preference of users for multimodal signals in critical situations, and spoken messages to abstract sounds [3]. As part of this experiment, a TOR was implemented according to the visual-auditive multimodal model, which is widely used in the literature [13].

Analysis of limitations

Two studies were conducted on the factors limiting the use of automation in vehicles currently on the market (level 2 SAE) and vehicles under test (level 3 SAE) [16]. The study of levels 2 vehicles focused on the extraction of limitations directly from the user manuals of a pool of 12 car models [6]. The study of levels 3 was carried out through the reports of disengagement of the tests of conditionally or fully automated vehicles from 2015 to 2018 [9], complementing the previous work of [12] and [11]. This state of the art made it possible to deduce the useful information to be transmitted to the driver via the HVI in order to increase his/her SA.

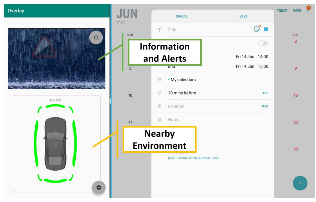

Figure 1: Android app in split-screen mode with secondary task

Figure 2: Driving Simulator

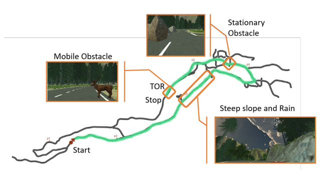

Figure 3: Scenario of the experiment

App Design and development

We designed an Android app aimed at informing the user about the vehicle's environment in relation with typical limitations of partially and conditionally automated vehicles, highlighted in the analysis phase. In particular, the aim of the app is maintaining the driver SA while s/he's engaging in secondary tasks in other apps of the tablet.

Driving simulator

We used a simulated environment [1] in which the following limitations were implemented: poor weather conditions (heavy rain), high terrain (steep slopes), stationary obstacles (rocks on the left lane) and a mobile obstacle (a deer crossing the road). All data about the vehicle's environment is streamed in real time to the Android application in data frames. Each limitation is associated with a severity level (from 0 to 5) that may correspond to different modality or a variation in its display. A TOR is also sent by this same data frame to the Android application.

Android mobile application

Currently, ADAS use technologies such as cameras or radars to detect objects in the nearby environment of the vehicle [2]. In the future, we can also imagine that vehicles will be able to benefit from emerging technologies such as V2V or V2I [15, 7] to be alerted in case of danger. Thus, the display of the Android application that we developed is based on this reflection and is divided into 2 parts (Figure 1):

- "Nearby environment": The proximity sensors are shown to indicate the presence of an element around the car. This module also provides information on the status of lane markings.
- "Information and Alerts": this part transmits data relating to specific events that require alerting the driver. They are displayed using different logos if the limitation is detected (such as steep slope). A change in weather conditions is characterized by a change in the background image. Different types of display are provided to distinguish the levels of severity.

The application is displayed in split screen mode and thus leaves the possibility of performing a secondary task. In the case of a TOR, a "TAKEOVER" text is displayed at the same time as a voice announcing "takeover". A vibration will also be activated (if available in the tablet).

Experiment and Results

Experiment

The main goal of this experiment was to validate the performance of the mobile application, its acceptance and the correct understanding of the information displayed. 5 participants (4 men and 1 woman) took part in the experiment. They have all a valid driving licence.

The experiment was performed on a fixed-base simulator built in a laboratory, as shown in Figure 2. The main driver's cab includes two car seats positioned side by side, seat belts, a Logitech G27 steering wheel, and acceleration, braking and clutch pedals. For the driving simulation, the software used is GENIVI [1]. The scenario used is modelling Yosemite National Park (USA) and proposes a conditionally automated driving mode for at least 20 minutes without interruption. This scenario has been modified to add the factors mentioned above that could limit the proper functioning of the vehicle.

During the whole experiment, the participant held in his hands a tablet (Samsung Galaxy Tab A brand) on which was displayed the application developed for this experiment as well as the secondary task in split screen mode.

Participants feedbacks

How to improve the design:

- P2: "A larger alert when an obstacle is detected"
- P3: "Make warnings more visible (e.g. change in background colour)".

. **Positive feedback:**

- P1: "The sound environment and the real look of the simulator"
- P2: "The application is intuitive, road disruptions are well indicated"
- P5: "I managed to play sudoku while I was driving without looking at the road."

Negative Feedback:

- P2: "At critical moments (presence of an obstacle for example), the urgency of the situation is not well perceived"
- P5: "A lot of stress in solving the sudoku because I expected the application to tell me to take control at any time, and it doesn't seem natural to me not to look at the road"

The participant was asked to perform a secondary task (Sudoku) on a tablet while the vehicle is driving. We chose this task because it requires enough concentration to neglect the monitoring of the vehicle's environment. If a TOR is given by the vehicle, the participant had to react to this request appropriately (braking and/or steer). For each participant, the vehicle passes through areas containing factors limiting the proper functioning of the autopilot (Figure 3). The first zone is characterized by heavy rain and a change in relief (steep slope). The second zone includes an obstacle (rock) on the opposite lane. The last area is the presence of an obstacle (deer) on the side of the road and then moving on the main lane, causing the vehicle to trigger a TOR.

Results
All participants correctly identified the following factors: adverse weather conditions (rain, snow, fog), high terrain and slippery/wet road. Concerning the factor "Temporary obstacles", only one participant did not identify this factor. In total, participants were able to identify 19 of the 20 proposed critical factors.

The overall design of the application received a score of 5.6 out of 7 (SD=1.02) and the design of logos a score of 6 out of 7 (SD=0.89). For the "Nearby environment" module displaying information relative to the vehicle's environment, participants rated its design with an average score of 6.4 out of 7 (SD=0.8). Then, the participants indicated that they understood the information transmitted by the application (logos, colours, wallpaper) with a score of 6 out of 7 (SD=0.63). Overall, they felt that this application would be useful in conditionally automated driving (6.2 out of 7, SD = 0.75). In addition to this, participants were asked for feedback (see left, P=Participant).

Discussion and Conclusion

The concept and design of the application received good acceptance and mostly positive feedback. The experiment has shown that each participant has succeeded in performing a secondary task, while receiving information about the vehicle's environment. In addition, the results of the questionnaire showed that although they were involved in the secondary task, all participants correctly identified all limiting factors except one participant (who identified 3 out of the 4 limiting factors). The results shows that the application is appreciated and seems to be effective. A comparison with/without the app must be conducted to prove the effectiveness of the application in increasing SA.

Considering this preliminary encouraging results, we will further investigate possible improvements for the application, with the purpose of further increasing the driver's SA and to develop effective takeover maneuvers. The main future lines of research are as follows:

- Define severity levels according to limitations and define different modalities and multimodalities by severity level and compare them during a new experiment.
- For a given limitation, it would also be interesting to test several levels of abstraction [18].
- Research on the amount of information to be transmitted. Indeed, some drivers would simply like to know that the vehicle has detected a component in front of the vehicle while others might want to know that the vehicle has detected a component in front and that it further identifies as a "pedestrian" [8]
- Since the multimodality of TOR is recognized as an indicator of the urgency of the situation [3], exploring new modalities could be relevant.

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